Study of Mechanical and Flexural Properties of Coconut Shell Ash Reinforced Epoxy Composites

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CERTIFICATE

This is to certify that the thesis entitled "**STUDY OF MECHANICAL AND FLEXURAL PROPERTIES OF COCONUT SHELL ASH REINFORCED EPOXY COMPOSITES**" submitted by Rahul Chanap (Roll Number: 108ME033) in partial fulfillment of the requirements for the award of Bachelor of Technology in the department of Mechanical Engineering, National institute of Technology, Rourkela is an authentic work carried out my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to elsewhere for the award of any degree.

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ABSTRACT

The present experimental work deals with the study of mechanical and flexural properties of coconut shell ash reinforced epoxy composites. Carbonisation method was used to prepare the coconut shell ash by heat treating the crushed coconut shell at a temperature of 600 and 800 degrees. Density, particle size and X-ray diffractometer methods were used for the characterization of coconut shell ash. Coconut shell ash epoxy composites were prepared by different filler concentration using hand lay-up technique. Specimens were cut from the fabricated laminate according to the ASTM standards for different experiments. For tensile and flexural test, samples were cut in dog-bone shape and flat bar shape respectively. It was observed that at 20 wt% of filler content, coconut shell ash which was heat treated at 800 degrees gives the best results for micro-hardness, flexural strength and tensile strength properties of the composite under consideration.

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CHAPTER 1

INTRODUCTION

INTRODUCTION

1.1. OVERVIEW OF COMPOSITES

Light, strong and corrosion-resistant, composite materials are being used in an increasing number of products as more manufactures discover the benefits of these versatile materials.In an advanced society like ours we all depend on composite materials in some aspect of our lives. Fiberglass, developed in the late 1940s, was the first modern composite and is still the most common. It makes up about 65 per cent of all the composites produced today and is used for boat hulls, surfboards, sporting goods, swimming pool linings, building panels and car bodies. We may well be using something made of fiberglass without knowing it. The strength and lightness of composites has made them particularly attractive for transportation. Composites have made airplanes lighter, more economical, and more affordable and solved problems such as cracking and metal fatigue.

Figure 1.1 Jet airplane

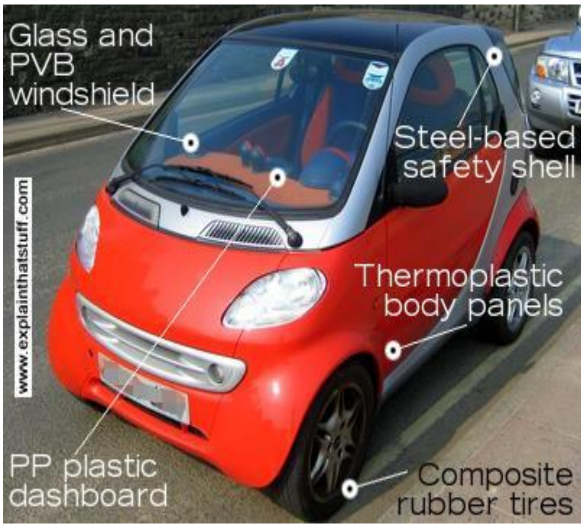

Figure 1.2 Composite cars

Composites are not just useful in making things fly. Cars of the future must be safer, more economical, and more environmentally friendly, and composites could help achieve all three. Although composites such as GRP have been used in the manufacture of automobile parts since the 1950s, most cars are still made from steel. High-temperature ceramic-matrix composites are also making possible cleaner-burning, more fuel-efficient engines for both cars and trucks. Composites are increasingly used in place of metals in machine tools. Apart from being lighter and stronger, they can offer better performance than metals at high temperatures and do not develop potentially dangerous weaknesses such as fractures and fatigue. Further, the need of composite for lighter construction materials and more seismic resistant structures has placed high emphasis on the use of new and advanced materials that not only decreases dead weight but also absorbs the shock & vibration through tailored microstructures. Composites are now extensively being used for rehabilitation/ strengthening of pre-existing structures that have to be retrofitted to make them seismic resistant, or to repair damage caused by seismic activity. Unlike conventional materials (e.g., steel), the properties of the composite material can be designed considering the structural aspects. The design of a structural component using composites involves both material and structural design. Composite properties (e.g. stiffness, thermal expansion etc.) can be varied continuously over a broad range of values under the control of the designer. Careful selection of reinforcement type enables finished product characteristics to be tailored to almost any specific engineering requirement. Whilst the use of composites will be a clear choice in many instances, material selection in others will depend on factors such as working lifetime requirements, number of items to be produced (run length), complexity of product shape, possible savings in assembly costs and on the experience & skills the designer in tapping the optimum potential of composites..

1.2. DEFINATION OF COMPOSITES

Composites are made by combining two or more natural or artificial materials to maximize their useful properties and minimize their weaknesses. One of the oldest and best-known composites, glass-fibers reinforced plastic (GRP), combines glass fibers (which are strong but brittle) with plastic (which is flexible) to make a composite material that is tough but not brittle. Composites are typically used in place of metals because they are equally strong but much lighter. Most composites consist of fibers of one material tightly bound into another material called a matrix. The matrix binds the fibers together somewhat like an adhesive and makes them more resistant to external damage, whereas the fibers make the matrix stronger and stiffer and help it resist cracks and fractures. Fibers and matrix are usually (but not always) made from different types of materials. The fibers are typically glass, carbon, silicon carbide, or asbestos, while the matrix is usually plastic, metal, or a ceramic material (though materials such as concrete may also be used).

1.3. TYPES OF COMPOSITES

Broadly, composite materials can be classified into three groups on the basis of matrix material. They are:

(a) Metal Matrix Composites (MMCs)

(b) Ceramic Matrix Composites (CMCs)

(c) Polymer Matrix Composites (PMCs)

(a) Metal Matrix Composites (MMCs)

Metal matrix composites, as the name implies, have a metal matrix. Examples of matrices in such composites include aluminium, magnesium and titanium. The typical fiber includes carbon and silicon carbide. Metals are mainly reinforced to suit the needs of design. For example, the elastic stiffness and strength of metals can be increased, while large co-efficient of thermal expansion, and thermal and electrical conductivities of metals can be reduced by the addition of fibers such as silicon carbide.

(b) Ceramic Matrix Composites (CMCs)

Ceramic matrix composites have ceramic matrix such as alumina, calcium, alumino silicate reinforced by silicon carbide. The advantages of CMC include high strength, hardness, high service temperature limits for ceramics, chemical inertness and low density. Naturally resistant to high temperature, ceramic materials have a tendency to become brittle and to fracture.

(c) Polymer Matrix Composites (PMCs)

The most common advanced composites are polymer matrix composites. These composites consist of a polymer thermoplastic or thermosetting reinforced by fiber (natural carbon or boron). These materials can be fashioned into a variety of shapes and sizes. They provide great strength and stiffness along with resistance to corrosion. The reason for these being most common is their low cost, high strength and simple manufacturing principles. Due to the low density of the constituents the polymer composites often show excellent specific properties.

1.4. WHY USE COMPOSITES

The greatest advantage of composite materials is strength and stiffness combined with lightness. By choosing an appropriate combination of reinforcement and matrix material, manufacturers can produce properties that exactly fit the requirements for a particular structure for a particular purpose.

Modern aviation, both military and civil, is a prime example. It would be much less efficient without composites. In fact, the demands made by that industry for materials that are both light and strong has been the main force driving the development of composites. It is common now to find wing and tail sections, propellers and rotor blades made from advanced composites, along with much of the internal structure and fittings. The airframes of some smaller aircraft are made entirely from composites, as are the wing, tail and body panels of large commercial aircraft.

In thinking about planes, it is worth remembering that composites are less likely than metals (such as aluminium) to break up completely under stress. A small crack in a piece of metal can spread very rapidly with very serious consequences (especially in the case of aircraft). The fibers in a composites act to block the widening of any small crack and to share the stress around.

The right composites also stand up well to heat and corrosion. This makes them ideal for use in products that are exposed to extreme environments such as boats, chemical-handling equipment and spacecraft. In general, composite materials are very durable.

Another advantage of composite materials is that they provide design flexibility. Composites can be moulded into complex shapes – a great asset when producing something like a surfboard or a boat hull.

The downside of composites is usually the cost. Although manufacturing processes are often more efficient when composites are used, the raw materials are expensive. Composites will never totally replace traditional materials like steel, but in many cases they are just what we need. And no doubt new uses will be found as the technology evolves. We haven’t yet seen all that composites can do.

1.5. EPOXY RESINS

Epoxy is a copolymer; that is, it is formed from two different chemicals. These are referred to as the "resin" and the "hardener". The resin consists of monomers or short chain polymers with an epoxide group at either end. Most common epoxy resins are produced from a reaction between -epichlorohydrin and bisphenol-A, though the latter may be replaced by similar 45 chemicals. The hardener consists of polyamine monomers, for example triethylenetetramine (TETA). When these compounds are mixed together, the amine groups react with the epoxide groups to form a covalent bond. Each NH group can react with an epoxide group, so that the resulting polymer is heavily cross linked, and is thus rigid and strong.

Softener (Araldite LY 556) made by CIBA GEIGY limited having the following outstanding properties has been used as the matrix material.

a. Excellent adhesion to different materials.

b. High resistance to chemical and atmospheric attack.

c. High dimensional stability.

d. Free from internal stresses.

e. Excellent mechanical and electrical properties.

f. Odourless, tasteless and completely nontoxic.

g. Negligible shrinkage.

1.6. NATURAL FIBER REINFORCED COMPOSITES

The interest in natural fiber-reinforced polymer composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap, completely or partially recyclable, and biodegradable. Plants, such as flax, cotton, hemp, jute, sisal, kenaf, pineapple, ramie, bamboo, banana, etc., as well as wood, used from time immemorial as a source of lignocellulosic fibers, are more and more often applied as the reinforcement of composites. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibers used for the manufacturing of composites. The natural fiber-containing composites are more environmentally friendly, and are used in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling panelling, partition boards), packaging, consumer products, etc.

Fibers are of two types: natural fiber and man- made or synthetic fiber. Natural fibers include those made from plant, animal and mineral sources. Natural fibers can be classified according to their origin: Animal fiber, Mineral fiber, Plant fiber.

The natural fiber composites can be very cost effective material for following applications:

1. Building and construction industry: panels for partition and false ceiling, partition boards, wall, floor, window and door frames, roof tiles, mobile or pre-fabricated buildings which can be used in times of natural calamities such as floods, cyclones, earthquakes, etc.
2. Storage devices: post-boxes, grain storage silos, bio-gas containers, etc.
3. Furniture: chair, table, shower, bath units, etc.
4. Electric devices: electrical appliances, pipes, etc.

1.7. COCONUT SHELL

Coconut shell is one of the most important natural fillers produced in tropical countries like Malaysia, Indonesia, Thailand, and Sri Lanka. Many works have been devoted to use of other natural fillers in composites in the recent past years and coconut shell filler is a potential candidate for the development of new composites because they have high strength and modulus properties along with the added advantage of high lignin content. The high lignin content makes the composites made with these filler more weather resistant and hence more suitable for application as construction materials. Coconut shell flour is also extensively used to make products like furnishing materials, rope etc. The shells also absorb less moisture due to its low cellulose content the report focuses on studying the effectiveness of coconut shell particles as a source of natural material for reinforcing epoxy resins towards their flexural properties.

1.8. COCONUT SHELL ASH

Many researches have made efforts for preparing carbon black from agricultural by-products such as coconut shell apricot stones, sugarcane bagasse, nutshells, forest residues and tobacco stems. Coconut shells have little or no economic value and their disposal is not only costly but may also cause environmental problems. Coconut shell is suitable for preparing carbon black due to its excellent natural structure and low ash content. Conversion of coconut shells into activated carbons which can be used as adsorbents in water purification or the treatment of industrial and municipal effluents would add value to these agricultural commodities, help reduce the cost of waste disposal, and provide a potentially cheap alternative to existing commercial carbons.

Carbonization of coconut shell ash

Coconut shells are cheap and readily available in high quantity. Coconut shell contains about 65 – 75% volatile matter and moisture which are removed largely during the carbonization process. The carbonization process involves converting the coconut shells to char (charcoal). The charring process (making of charcoal) is known as the Pyrolysis, which is chemical decomposition of the shell by heating in the absence of oxygen. During the carbonization of coconut shells, volatiles amounting to 70% of the mass of coconut shells on dry weight basis are released to the atmosphere, yielding 30% of coconut shell mass of charcoal. The volatile released during the carbonization process is Methane, CO_2 and wide range of organic vapors. The carbonization temperature range between 400 and850℃, sometimes reaches 1000℃.

1.9. AIM OF THE PRESENT WORK

The main objective of this work is to prepare a PMC using coconut shell ash as reinforcement and epoxy as matrix material and to study its mechanical properties and flexural properties. Density, particle size and XRD tests were used for the characterization of coconut shell ash. Out of the available manufacturing procedures we have adopted the hand lay-up technique to prepare the PMC. Different volume % of filler of coconut shell ash has been mixed with the matrix material and specimens were prepared for mechanical studies.

CHAPTER 2

LITERATURE SURVEY

LITERATURE SURVEY

2.1. NATURAL FIBER BASED POLYMER COMPOSITES

S. Luo and A.N. Netravali [1] studied the tensile and flexural properties of the green composites with different pineapple fiber content and compared with the virgin resin. H. Belmares, A. Barrera, and M. Monjaras [2] found that sisal, henequen and palm fiber have very similar physical, chemical, and tensile properties. M. Cazaurang, P. Herrera, I. Gonzalez, and V.M. Aguilar [3] carried out a systematic study on the properties of henequen fiber and pointed out that these fibers have mechanical properties that are suitable for reinforcing thermoplastic resins. E.M. Ahmed, B. Sahari, and P. Pedersen [4] carried out research work on filament wound cotton fiber reinforced for reinforcing high density polyethylene (HDPE) resin. A.A. Khalid, B. Sahari, and Y.A. Khalid [5] studied the use of cotton fiberreinforced epoxy composites along with glass fiber reinforced polymers. M.Y.A. Fuad, S. Rahmad, and M.R.N., Azlan [6] investigated the new type wood-based filler derived from oil palm wood flour (OPWF) for bio-based thermoplastics composites by thermo-gravimetric analysis and the results are very promising.

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2.1. COCONUT SHELL BASED POLYMER COMPOSITES

S.M. Sapuan, M. Harimi and M. A. Maleque [7] presented the tensile and flexural properties of composites made from coconut shell filler particles and epoxy resin. The tensile and flexural tests of composites based on coconut shell filler particles at three different filler contents viz. 5%, 10%, and 15% were done. J. Sarki, S.B. Hassan, V.S. Aigbodion, J.E. Oghenevweta [8] studied coconut shell filled composites which were prepared from epoxy polymer matrix containing up to 30 wt% coconut shell fillers. The effects of coconut shell particle content on the mechanical properties of the composites were investigated. P.B Madakson, D.S.Yawas and A. Apasi [9] concluded that the coconut shell ash can withstand a temperature of up to 1500˚C with a density of 2.05g/cm³. That means this ash can be use in production light weight MMCs component with good thermal resistance. B. Ramaraj, P. Poomalai [10] studied the Poly (vinyl alcohol) (PVA) composites with 10, 20, 33, and 55 wt % of coconut shell (CCS) powder and it was observed that the introduction of CCS powder varies the tensile strength and affects percentage of elongation, tear and burst strengths, moisture content, density, and swelling capacity. Prof. Sandhyarani Biswas, Sanjay Kindo [11] studied the mechanical behavior of coir fiber reinforced polymer matrix composites and observed that that the mechanical properties of the composites such as micro-hardness, tensile strength, flexural strength, impact strength etc. of the composites are also greatly influenced by the fibre lengths. Prof. Sandhyarani Biswas, Sanjay Kindo [12] studied the processing and characterization of natural fiber reinforced polymer composites and observed that impact velocity, erodent size and fiber loading were the significant factors in a declining sequence affecting the erosion wear rate.

CHAPTER 3

EXPERIMENTATION

EXPERIMENTATION

The methodology for performing the experiments towards determining the validity of the thesis consists of several phases, namely, the processing of the coconut shell (carbonization), density measurement, particle size analysis, XRD analysis, specimen preparation, mechanical testing, micro-hardness, tensile strength and flexural strength.

3.1. THE PROCESSING OF THE COCONUT SHELL (CARBONIZATION)

The coconuts were procured from a nearby local temple. The coconuts were broken manually to drain out the water. The 40 coconut half shells were sun-dried for three days. Sun-drying was necessary to ease removal of the meat from the inner shells of the coconut pieces. After scraping the meat from the inner shells, the inner portions of the shells were cleaned using knives. The fibers on the outer shells were also scraped and cleaned. Emery paper was used to clean the outer shells.

The cleaned coconut shells obtained from were cut into pieces of dimensions of 1 sq.cm. using hammer and were put in stainless steels containers. The containers were then kept into muffle furnace for carbonization (carbonization is the production of charred carbon from a source material. The process is generally accomplished by heating the source material usually in the absence or limited amount of air to a temperature sufficiently high to dry and volatilize substances in the carbonaceous material). The carbonization temperature selected as600 and 800 degrees. After a soak time of 4 hours, the sample gets carbonized. As the furnace cools down, containers were taken out. The collected char was ground to form powder using a grinding machine. The powder was then sieved to a size of 212 μm**.**

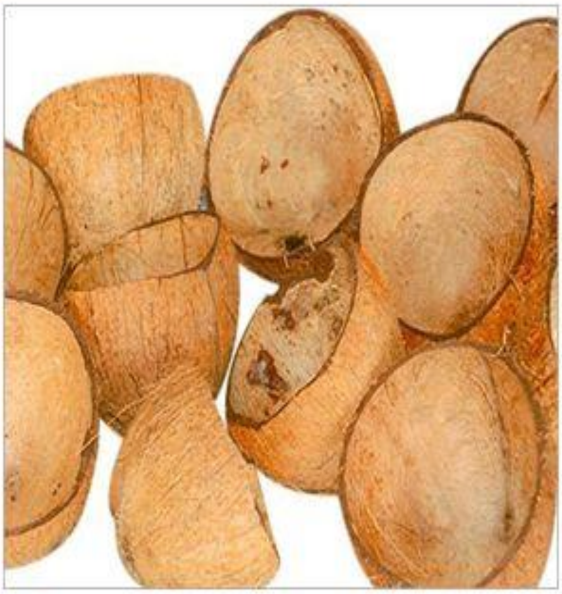


Figure 3.1 Coconut shells   Figure 3.2 Muffle furnace

Figure 3.3 Coconut shell ash

3.2. DENSITY MEASUREMENT

Density determination by pycnometer is a very precise method. The theoretical density of coconut shell ash using pycnometer can be obtained by the following equation:

$\rho = [(W2\text{-}W1) / \{(W4\text{-}W1) - (W3\text{-}W2)\}] \times$ Density of kerosene (0.816 g/cc)

where W1 is the weight of the empty clean and dry pycnometer,W2 is the weight of the pycnometer containing the sample, W4 is the weight of the pycnometer containing the kerosene, W3 is the weight of the pycnometer containing the sample and kerosene. Using the formula, the value of density was measured.

Figure 3.4 Pycnometer

3.4.PARTICLE SIZE ANALYSIS

The particle size and size distribution of the coconut shell ash particles has been studied by laser scattering technique (Malvern MASTER SIZER 2000, U.K.) in Metallurgical and Materials Engineering Department, NIT Rourkela. The ash particles were ultrasonically dispersed in water using sodium hexametaphosphate as dispersant.

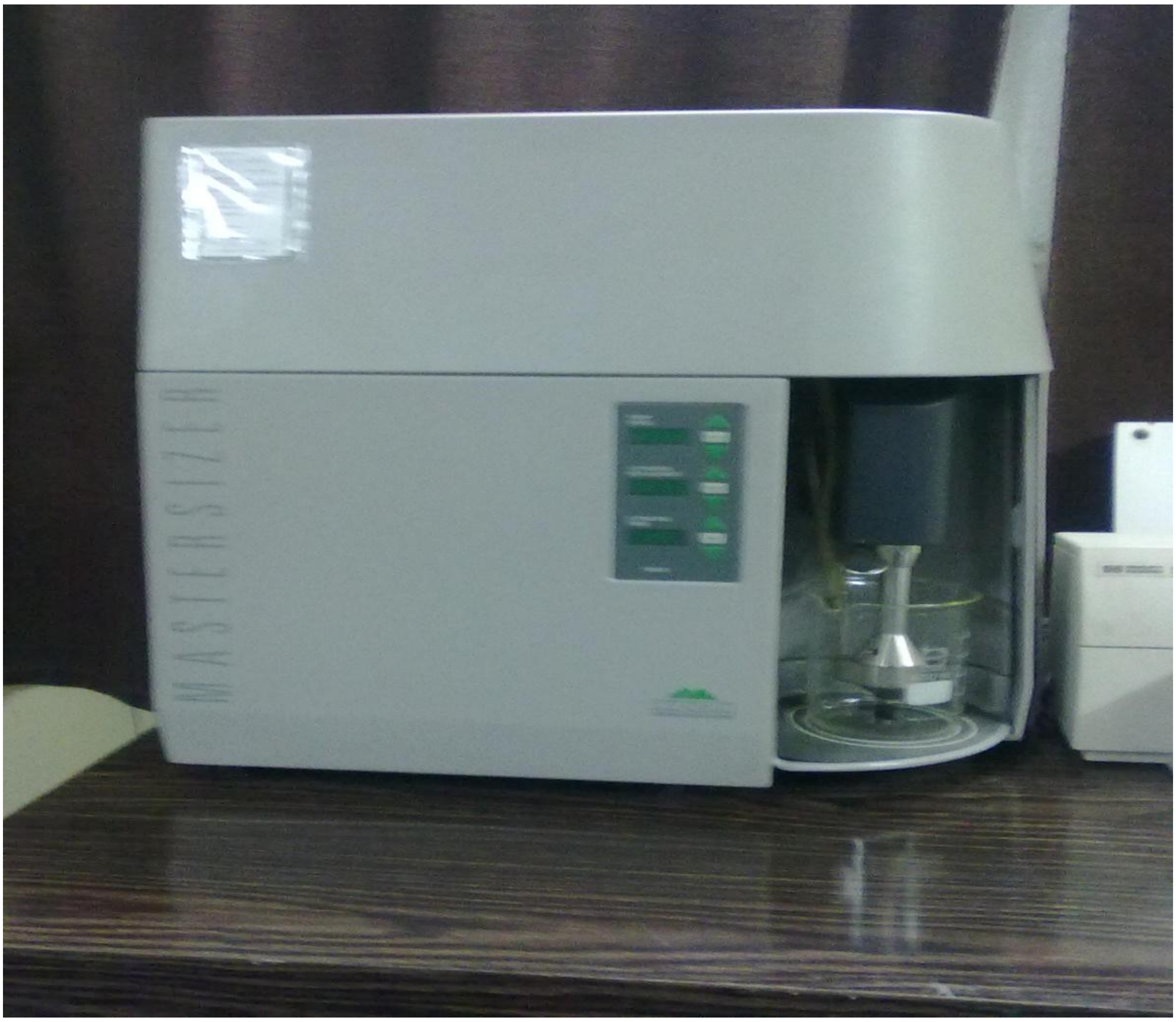


Figure 3.5 Particle size analyzer

3.4.XRD ANALYSIS

The XRD (X-ray Diffractometer, X'Pert MPD) analysis of the coconut shell ash was carried out in Metallurgical and Materials Engineering Department. Phase analysis was studied using room temperature powder X-ray diffraction (Model: PW 3040 Diffractometer, Philips, Holland) will filtered 1.54 Å Cu Kα radiation. Samples (coconut shell at 600 degrees) are scanned in a continuous mode with a scanning rate of 3 degrees/min.

Figure 3.6 X-ray diffractometer (X' Pert MPD)

3.5. SPECIMEN PREPARATION

The sets of ball particles were used to prepare the reinforced composites. Epoxy LY 556 resin, chemically belonging to the 'epoxide' family is used as the matrix. Its common name is BisphenolA Diglycidyl Ether. The low temperature curing epoxy resin (Araldite LY 556) and corresponding hardener (HY951) are mixed in a ratio of 10:1 by weight as recommended. The epoxy resin and the hardener are supplied by Ciba Geigy India Ltd. The weight percent ratio of coconut powder and epoxy + hardener was selected as 10% : 90%. This filler weight percent was chosen because it had been reported by Harimi et al [8] that reinforcement of epoxy with a filler weight percent of 15% had clearly noticeable effect on the mechanical properties of the composite. The density of the epoxy + hardener was found to be 1.16 g/cc from the MSDS of the manufacture. The density was determined as 1.3847 g/cc (at 600 degrees) and 2.339 g/cc (at 800 degrees).

Mold preparation

Wooden board was taken and a Teflon sheet placed on it. A frame with square size stick of dimensions (15x6x0.6)cm was made using hammer. Heavy duty silicon spray was spread inside the frame to easily release the mould. The mixture was poured in to the frame and spread it thoroughly in order to avoid voids. When it will slightly harden, put one Teflon sheet on it and pressed it with various loads. After one day, the specimens ware taken out from the frame.

Figure 3.7 Specimen for Flexural test

Figure 3.8 Specimen for Tensile test

3.6. MECHANICAL TESTING

The characterization of the composites reveals that the volume % of fiberis having significant effect on the mechanical properties of composites. Mechanical testing includes testing of micro-hardness, tensile strength and flexural strength respectively.

3.6.1. MICRO-HARDNESS

Hardness is a mechanical property which represents the resistance of the material to penetration and scratching, it is measured by the distance of indentation and recovery that occurs when the indenter is pressed into the surface under constant load. Leitz micro-hardness tester was used for Hardness measurement. This tester had a diamond indenter, in the form a right pyramid with a square base and an angle 136° between opposite faces, is forced in to the material under a load ranging from 0.3 to 3 N.

Figure 3.9 Micro-hardness testing machine

3.6.2. TENSILE STRENGTH

Tensile strength indicates the ability of a composite material to withstand forces that pull it apart as well as the capability of the material to stretch prior to failure.The commonly used specimens for tensile test are the dog-bone type and the straight side type with24end tabs. During the test a uni-axial load is applied through both the ends of the specimen.The tensile strength were conducted according to the ASTM 790 standard on computerized universal testing machine INSTRON H10KS. The value of gauge length (L), width (d) and thickness (t)of the test specimen used in the experimentation as 100 mm, 12 mm and 6 mm. The tests were performed with a constant strain rate of 0.5 mm/min.

Tensile strength was calculated by the formula: S= F/A where F is the maximum load (in newtons); A is the area of the specimen.

Tensile modulus and modulus of elasticity was determined as: $E = FL/A\Delta L$ where F is the maximum load; L is the distance between the supports; A is the area of the specimen, and ΔL is the deflection (in millimeters) corresponding to the load F.

Figure 3.10 Tensile strength testing machine

3.6.3. FLEXURAL STRENGTH

Flexural strength is the ability of the composite material to withstand bending forces applied perpendicular to its longitudinal axis. The inter-laminar shear strength (IILS) is the maximum shear stress existing between layers of laminated material. Flexural test were performed using 3-point bending method according to ASTM D790-03 standard procedure. The specimens were tested at a crosshead speed of 0.5 mm/min. The loading arrangement in the specimen was shown in figure. The value of gauge length (L), width (d) and thickness (t)of the test specimen used in the experimentation as 100 mm, 20 mm and 6 mm.

The flexural strength was calculated by the formula: $\sigma = 3FL / 2bt^2$where F is the maximum load (in newtons); L is the distance between the supports (in millimeters); b is the width of the specimen (in millimeters) and t, the thickness (in millimeters).

The flexural modulus was determined as: $E = FL^3/4bt^3d$where F is the maximum load; L is the distance between the supports; b is the width of the specimen, t is the thickness of the specimen, and d is the deflection (in millimeters) corresponding to load F.

The inter-laminar shear strength was calculated by the formula: IILS = 3FL / 4btwhere F is the maximum load (in newtons); L is the distance between the supports (in millimeters); b is the width of the specimen (in millimeters) and t, the thickness (in millimeters).

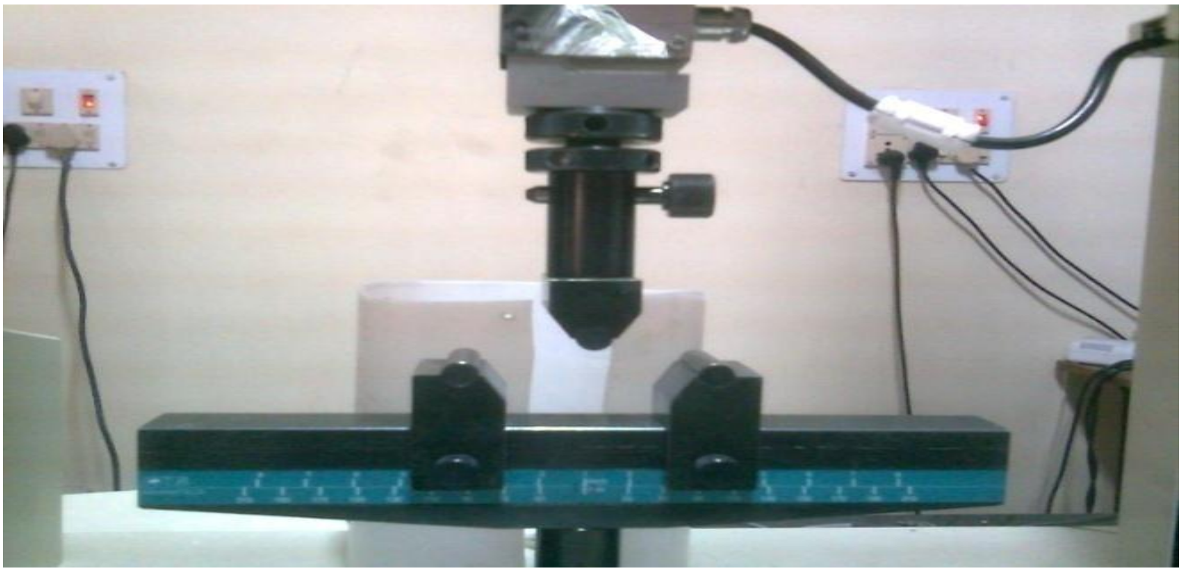


Figure 3.11 Flexural strength testing machine

CHAPTER 4

RESULTS, DISCUSSIONS AND CONCLUSIONS

4.1. DENSITY MEASUREMENT

Table 4.1

Density of neat epoxy, coconut shell ash at 600 degrees and coconut shell ash at 800 degrees

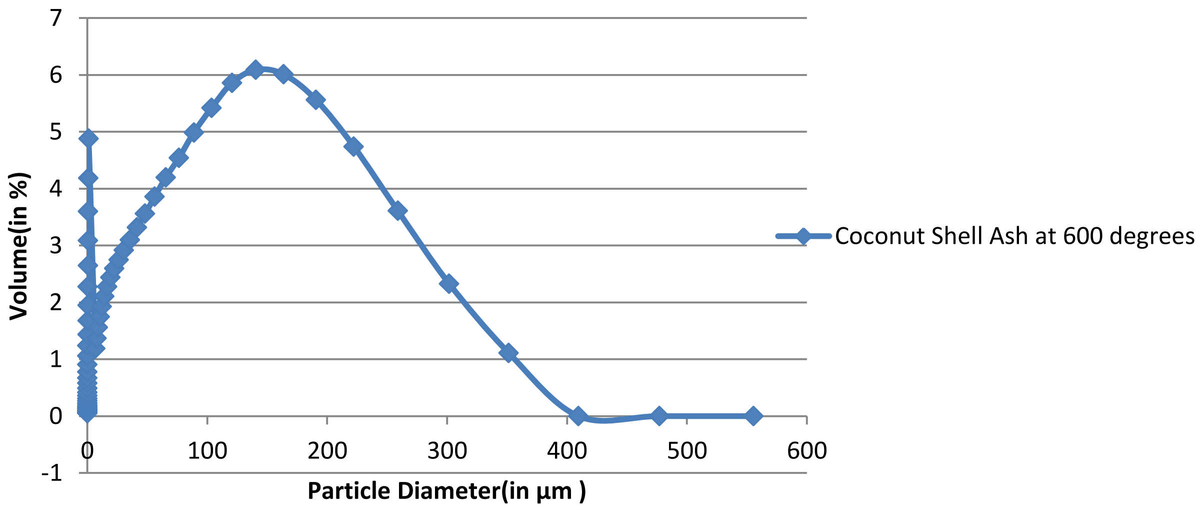
Sample	Density, ρ (g/cc)
Neat Epoxy	1.16
Coconut shell ash at 600 degrees	1.384
Coconut shell ash at 800 degrees	2.339

Table 4.2

Density of coconut shell ash reinforced epoxy composites with different volume % of filler

Volume % of filler	Density at 600 degrees, ρ (g/cc)	Density at 800 degrees ,ρ (g/cc)
5	2.04	1.14
10	1.186	1.084
20	1.248	1.095
30	1.049	1.023

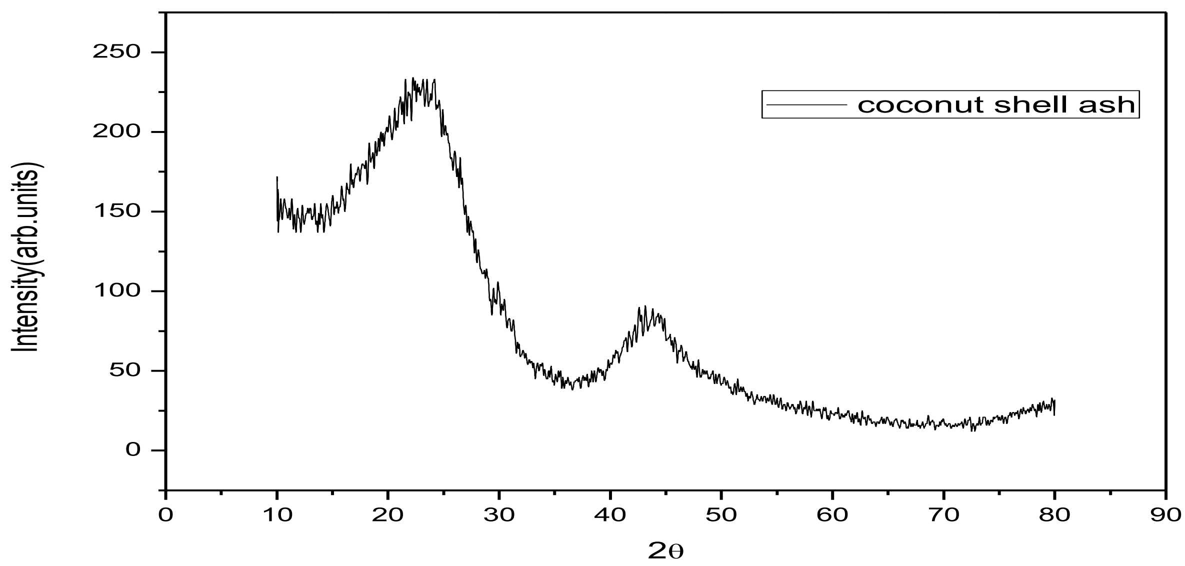
4.2. PARTICLE SIZE ANALYSIS



Graph 4.1 Particle size distribution

From the particle size analysis report, the coconut shell ash (at 600 degrees) shows graph with very narrow range of particle size distribution along with the symmetric behavior of curve along with a small hump. This indicates the particle size distribution ranging from 0.1 to 500 microns. The graph also clear shows that the average particle size is found to be 140.58 microns.

4.3. XRD ANALYSIS



Graph 4.2 XRD pattern of coconut shell ash (at 600 degrees)

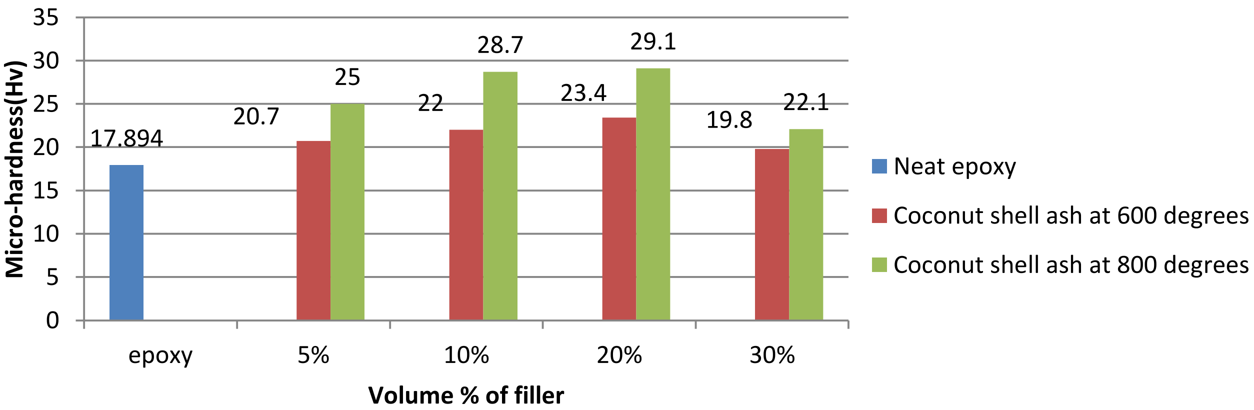
The XRD pattern obtained reveals that, the major peaks of diffraction are 12.2˚, 17.65˚, 23.45˚ and their inter-planar distance, 3.29221Å, 5.575Å, 3.71667Å and planes, (0 0 1), (0 0 6), (0 0 9) as $Si0_2$, C and C respectively.

4.4. MICRO-HARDNESS

Table 4.3

Hardness of neat epoxy, coconut shell ash reinforced epoxy composites with different volume % of filler

Hardness of neat epoxy (Hv)	Volume % of filler	Hardness of coconut shell ash reinforced epoxy composites at 600 degrees (Hv)	Hardness of coconut shell ash reinforced epoxy composites at 800 degrees (Hv)
17.89	5	20.7	25.0
	10	22.0	28.7
	20	23.4	29.1
	30	19.8	29.1



Graph 4.3 Micro-hardness versus volume % of filler

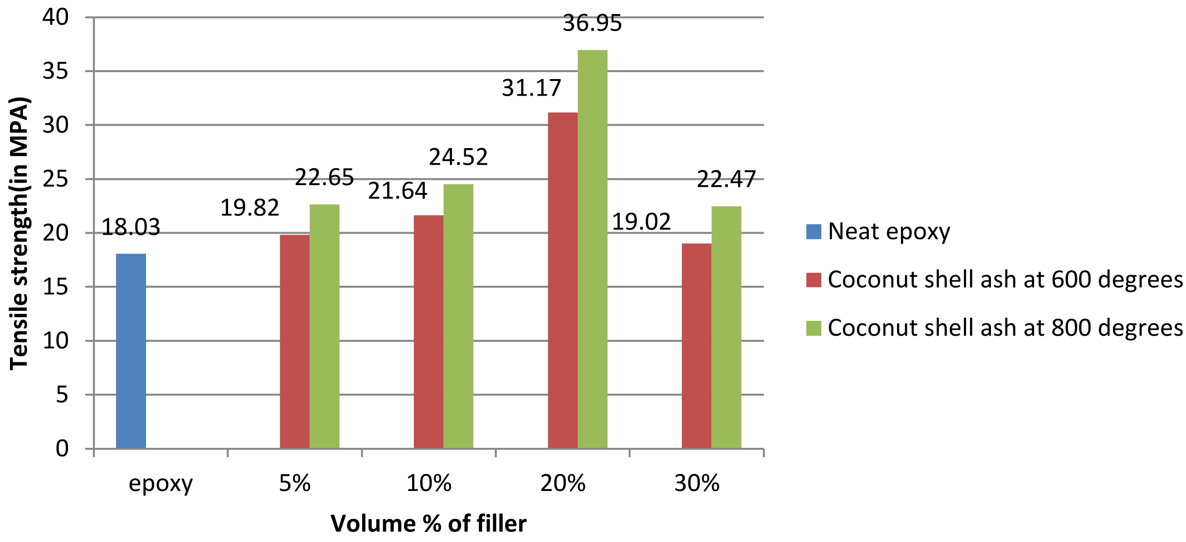
From the above graph of micro-hardness versus volume % of filler, in case of neat epoxy micro-hardness increases sharply till 20% of filler and then decreases with further increase in volume % of filler. While going through coconut shell ash, which was formed at 600 degrees also shows similar behavior with increase in micro-hardness till 20% of filler at its best and then decreases with further increase in volume % of filler. When the same coconut shell ash which is heat treated at 800 degrees gives highest micro-hardness at 20% of filler with comparison to coconut shell ash heat treated at 600 degrees and neat epoxy.

4.5. TENSILE STRENGTH

Table 4.4

Tensile strength and tensile modulus for neat epoxy and coconut shell ash reinforced epoxy composites with different volume % of filler

Sample	Volume % of filler	Tensile Load, F (Newtons)	Extension (mm)	Tensile strength, S (MPA)	Tensile modulus, E (GPA)
Neat epoxy				18.03	521
Coconut shell ash at 600 degrees	5	1623	4.59	19.82	474.91
	10	1690	4.11	21.64	579.29
	20	2437	4.908	31.17	698.63
	30	1431	2.69	19.02	777.63
Coconut shell ash at 800 degrees	5	1723	3.05	22.65	758.99
	10	1865	3.46	24.52	708.58
	20	2922	8.56	36.95	431.71
	30	1565	6.07	22.47	368.64



Graph 4.5 Tensile strength versus volume % of filler

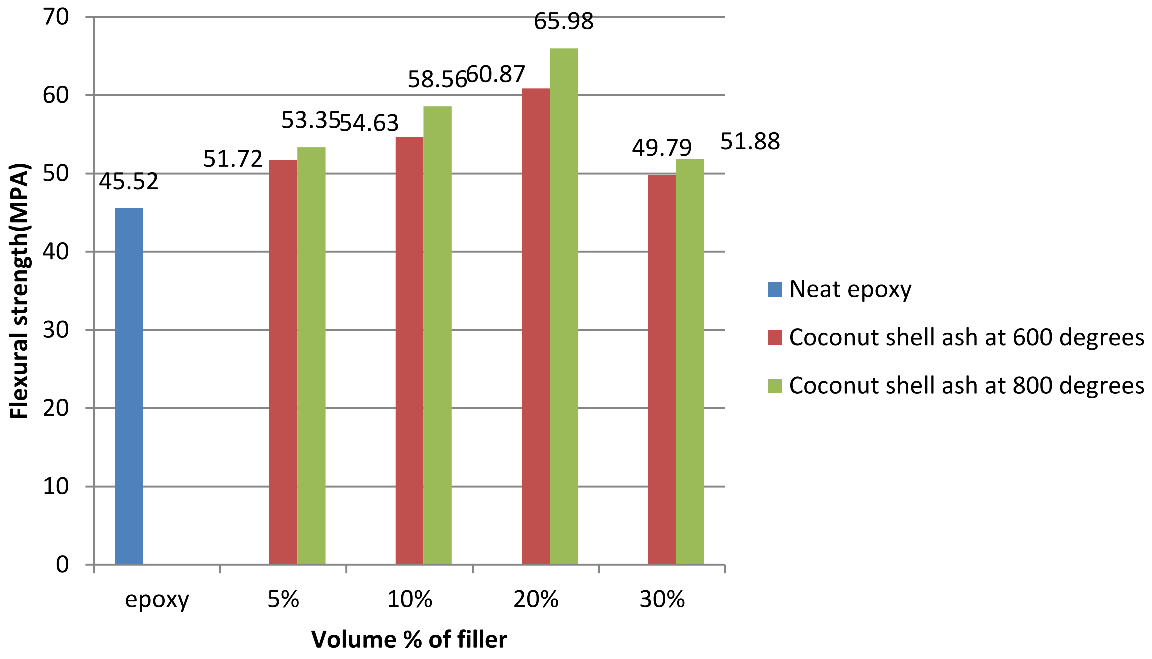
From the above graph of tensile strength versus volume % of filler, in case of neat epoxy tensile strength increases sharply till 20% of filler and then decreases with further increase in volume % of filler. While going through coconut shell ash, which was formed at 600 degrees also shows similar behavior with increase in tensile strength till 20% of filler at its best and then decreases with further increase in volume % of filler. When the same coconut shell ash which is heat treated at 800 degrees gives highest tensile strength at 20% of filler with comparison to coconut shell ash heat treated at 600 degrees and neat epoxy.

4.6. FLEXURAL STRENGTH

Table 4.5

Flexural strength, flexural modulus and interlaminar shear strength for neat epoxy &coconut shell ash reinforced epoxy composites with different volume % of filler

Sample	Volume % of filler	Flexural Load, F (Newtons)	Extension (mm)	Flexural strength, σ (MPA)	Interlaminar shear strength, IILS (MPA)	Flexural modulus, E (GPA)
Neat epoxy				45.52		632
Coconut shell ash at 600 degrees	5	211	4.77	51.72	1.55	3011.63
	10	236	4.36	54.63	1.64	3480.48
	20	226	3.64	60.87	1.80	4723.58
	30	239	4.16	49.79	1.49	3324.76
Coconut shell ash at 800 degrees	5	225	2.72	53.35	1.63	5359.39
	10	253	3.33	58.56	1.76	4885.29
	20	245	3.11	65.98	1.95	5993.35
	30	249	1.59	51.88	1.56	9062.72



Graph 4.5 Flexural strength versus volume % of filler

From the above graph of flexural strength versus volume % of filler, in case of neat epoxy flexural strength increases sharply till 20% of filler and then decreases with further increase in volume % of filler. While going through coconut shell ash, which was formed at 600 degrees also shows similar behavior with increase in flexural strength till 20% of filler at its best and then decreases with further increase in volume % of filler. When the same coconut shell ash which is heat treated at 800 degrees gives highest flexural strength at 20% of filler with comparison to coconut shell ash heat treated at 600 degrees and neat epoxy.

CONCLUSIONS

From the analysis of the results and discussion given above, the following conclusions can be made. In micro-hardness test, it was observed that at 20 wt % of filler content, coconut shell ash which was heat treated at 800 degrees gives the best results in comparison to neat epoxy and coconut shell heat treated at 600 respectively. In tensile and flexural test, coconut shell ash which was heat treated at 800 degrees also shows similar behavior with increase in strength till 20% of filler at its best and then decreases with further increase in volume % of filler. The average particle size of the coconut shell ash at 600 degree was found to be 140.58 microns. The XRD analysis of the coconut shell ash at 600 degrees (uncalcined) revealed that C has the highest percentage of all the compound and element present in the coconut shell ash.

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